

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patent Application for:

ELEMENTARY STREAM PARTIAL ENCRYPTION

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Docket Number: SNY-R4646.03

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12 **ELEMENTARY STREAM PARTIAL ENCRYPTION**
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CROSS REFERENCE TO RELATED DOCUMENTS

16 This application is related to U.S. provisional patent application serial
17 number 60/296,673 filed June 6, 2001 to Cadelore, et al. entitled "Method for
18 Allowing Multiple CA Providers to Interoperate in a Content Delivery System by
19 Sending Video in the Clear for Some Content, and Dual Carriage of Audio and Dual
20 Carriage of Video and Audio for Other Content", and provisional patent application
21 serial number 60/304,241 filed July 10, 2001 to Unger et al., entitled "Independent
22 Selective Encryptions of Program Content for Dual Carriage", and provisional patent
23 application serial number 60/304,131 filed July 10, 2001 to Cadelore et al.,
24 entitled "Method for Allowing Multiple CA Providers to Interoperate in a Content
25 Delivery System by Partial Scrambling Content on a Time Slice Basis" and to U.S.
26 provisional patent application serial no. 60/_____, filed on October 26, 2001
27 to Cadelore et al., entitled "Television Encryption Systems", docket number SNY-
28 R4646P, which are hereby incorporated herein by reference.

1 This application is being filed simultaneously with patent applications
2 docket number SNY-R4646.01 entitled "Critical Packet Partial Encryption" to Unger
3 et al., serial number _____; docket number SNY-R4646.02 entitled
4 "Time Division Partial Encryption" to Candelore et al., serial number _____;
5 docket number SNY-R4646.04 entitled "Partial Encryption and PID Mapping" to
6 Unger et al., serial number _____; and docket number SNY-R4646.05
7 entitled "Decoding and Decrypting of Partially Encrypted Information" to Unger et
8 al., serial number _____. These simultaneously filed patent applications
9 are hereby incorporated by reference herein.

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18 **FIELD OF THE INVENTION**

19 This invention relates generally to the field of encryption systems. More
20 particularly, this invention relates to systems, methods and apparatus for providing
21 partial encryption and decryption of digital television signals.

22

23 **BACKGROUND OF THE INVENTION**

24 Television is used to deliver entertainment and education to viewers. The
25 source material (audio, video, etc.) is multiplexed into a combined signal which is
26 then used to modulate a carrier. This carrier is commonly known as a channel. (A
27 typical channel can carry one analog program, one or two high definition (HD)
28 digital program(s), or several (e.g. nine) standard definition digital programs.) In a
29 terrestrial system, these channels correspond to government assigned frequencies

1 and are distributed over the air. The program is delivered to a receiver that has a
2 tuner that pulls the signal from the air and delivers it to a demodulator, which in turn
3 provides video to a display and audio to speakers. In a cable system the
4 modulated channels are carried over a cable. There may also be an in-band or out-
5 of-band feed of a program guide indicating what programs are available and the
6 associated tuning information. The number of cable channels is finite and limited
7 by equipment/cable bandwidth. Cable distribution systems require a significant
8 capital investment and are expensive to upgrade.

9 Much of television content is valuable to its producers, therefore copyright
10 holders want to control access and restrict copies. Examples of typically protected
11 material include feature films, sporting events, and adult programming. Conditional
12 access (CA) systems are used to control availability of programming in content
13 delivery systems such as cable systems. CA systems come as matched sets –
14 one part is integrated into the cable system headend and encrypts premium
15 content, the other part provides decryption and is built into the set-top boxes (STB)
16 installed in user's homes. Several CA systems are used in the cable industry
17 including those provided by NDS (Newport Beach, CA), Motorola (Schaumberg, IL)
18 and Scientific Atlanta (Atlanta, GA). This matched set aspect of CA systems has
19 the effect that the "legacy" vendor is locked in as the supplier of additional STBs.
20 Since the various technologies for conditional access are not mutually compatible
21 (and are often proprietary), any new potential supplier is forced to license the
22 legacy CA. Thus, the cable operator finds itself unable to acquire newer technology
23 or competing technology from other set-top box manufacturers since the technology
24 owners are often unwilling to cooperate, or charge reasonable license fees. This
25 inflexibility can be especially troublesome when cable companies with disparate
26 CA systems are merged. Service providers would like more than one source for
27 STBs for any number of reasons.

28 Once a cable operator picks an encryption scheme, it is difficult to change
29 or upgrade the content encryption scheme without introducing a backward
30 compatible decoding device (e.g. set-top box). Providing multiple mode capability

1 in new set-top boxes to handle multiple encryption systems can add substantial
2 cost to any new set-top box, providing that the technology can be made available
3 to the STB vendor to provide the multiple decryption capability.

4 The only known current option to avoiding domination by the legacy vendor
5 (short of wholesale replacement) is using “full dual carriage”. Full dual carriage
6 means that transmission is duplicated for each encrypted program – once for each
7 type of CA encryption to be used. To provide full dual carriage, the headend is
8 enhanced to provide each form of CA simultaneously. Legacy STBs should not be
9 impacted and should continue to perform their function despite any change.
10 However, full dual carriage often comes at an unpalatable price because of the
11 bandwidth impact, thus reducing the number of unique programs available.
12 Generally, the number of premium channels suffers so that the number of options
13 available to the viewer are limited and the value that can be provided by the cable
14 operator is restricted.

15 A conventional cable system arrangement is depicted in **FIGURE 1**. In such
16 a system, the cable operator processes audio/video (A/V) content 14 with CA
17 technology from manufacturer A (system A) using CA encryption equipment 18
18 compliant with system A at the cable system -headend 22. The encrypted A/V
19 content along with system information (SI) 26 and program specific information
20 (PSI) 27 is multiplexed together and transmitted over the cable system 32 to a
21 user's STB 36. STB 36 incorporates decrypting CA equipment from system A
22 (manufacturer A) 40 that decrypts the A/V content. The decrypted A/V content can
23 then be supplied to a television set 44 for viewing by the user.

24 In a cable system such as that of **FIGURE 1**, digital program streams are
25 broken into packets for transmission. Packets for each component of a program
26 (video, audio, auxiliary data, etc.) are tagged with a packet identifier or PID. These
27 packet streams for each component of all programs carried within a channel are
28 aggregated into one composite stream. Additional packets are also included to
29 provide decryption keys and other overhead information. Otherwise unused

1 bandwidth is filled with null packets. Bandwidth budgets are usually adjusted to
2 utilize about 95% of the available channel bandwidth.

3 Overhead information usually includes guide data describing what programs
4 are available and how to locate the associated channels and components. This
5 guide data is also known as system information or SI. SI may be delivered to the
6 STB in-band (part of the data encoded within a channel) or out-of-band (using a
7 special channel dedicated to the purpose). Electronically delivered SI may be
8 partially duplicated in more traditional forms - grids published in newspapers and
9 magazines.

10 In order for a viewer to have a satisfying television experience, it is generally
11 desirable that the viewer have clear access to both audio and video content. Some
12 analog cable systems have used various filtering techniques to obscure the video
13 to prevent an unauthorized viewer from receiving programming that has not been
14 paid for. In such a system, the analog audio is sometimes sent in the clear. In the
15 Motorola VideoCipher 2 Plus system used in C-band satellite transmissions, strong
16 digital audio encryption is used in conjunction with a relatively weak protection of
17 the analog video (using sync inversion). In airline in-flight movie systems, the
18 availability of audio only through rental of headphones has been used to provide the
19 full audio and video only to paying customers.

20

21 BRIEF DESCRIPTION OF THE DRAWINGS

22 The features of the invention believed to be novel are set forth with
23 particularity in the appended claims. The invention itself however, both as to
24 organization and method of operation, together with objects and advantages
25 thereof, may be best understood by reference to the following detailed description
26 of the invention, which describes certain exemplary embodiments of the invention,
27 taken in conjunction with the accompanying drawings in which:

28 **FIGURE 1** is a block diagram of a conventional conditional access cable
29 system.

1 **FIGURE 2** is a block diagram of a system consistent with one embodiment
2 of the present invention in which dual encrypted audio is transmitted along with
3 clear video.

4 **FIGURE 3** is a block diagram of a system consistent with an embodiment
5 of the present invention in which portions of programming are dual encrypted
6 according to a time slice mechanism.

7 **FIGURE 4** is a flow chart of a dual encryption process consistent with certain
8 embodiments of the present invention.

9 **FIGURE 5** is a flow chart of a decryption process consistent with certain
10 embodiments of the present invention.

11 **FIGURE 6** is a block diagram of a system consistent with an embodiment
12 of the present invention in which portions of programming are dual encrypted on a
13 packet basis.

14 **FIGURE 7** is a flow chart of a dual encryption process consistent with certain
15 embodiments of the present invention.

16 **FIGURE 8** is a flow chart of a decryption process consistent with certain
17 embodiments of the present invention.

18 **FIGURE 9** is a block diagram of a system consistent with an embodiment
19 of the present invention in which system information is encrypted and programming
20 is sent in the clear.

21 **FIGURE 10** is a block diagram of a generic system consistent with various
22 embodiments of the present invention.

23 **FIGURE 11** is a block diagram of a first embodiment of implementation of
24 an encryption system consistent with embodiments of the present invention in a
25 cable system headend.

26 **FIGURE 12** is a block diagram of a second embodiment of implementation
27 of an encryption system consistent with embodiments of the present invention in
28 a cable system headend.

29 **FIGURE 13** is a flow chart of an overall encryption process used to

1 implement certain embodiments of the present invention in a cable system
2 headend.

3 **FIGURE 14** is a block diagram of a first embodiment of a set-top box
4 implementation of a decoding system consistent with embodiments of the
5 present invention.

6 **FIGURE 15** is a block diagram of a second embodiment of
7 implementation of a decoding system consistent with embodiments of the
8 present invention in a cable system STB.

9 **FIGURE 16** is a block diagram of a third embodiment of implementation
10 of a decoding system consistent with embodiments of the present invention in a
11 cable system STB.

12 **FIGURE 17** illustrates the PID remapping process carried out in one
13 embodiment of a set-top box PID re-mapper.

14 **FIGURE 18** is a block diagram of an exemplary decoder chip that can be
15 utilized in a television set-top box consistent with the present invention.

17 **DETAILED DESCRIPTION OF THE INVENTION**

18 While this invention is susceptible of embodiment in many different forms,
19 there is shown in the drawings and will herein be described in detail specific
20 embodiments, with the understanding that the present disclosure is to be
21 considered as an example of the principles of the invention and not intended to limit
22 the invention to the specific embodiments shown and described. In the description
23 below, like reference numerals are used to describe the same, similar or
24 corresponding parts in the several views of the drawings. The terms "scramble"
25 and "encrypt" and variations thereof are used synonymously herein. Also, the term
"television program" and similar terms can be interpreted in the normal
conversational sense, as well as a meaning wherein the term means any segment
of A/V content that can be displayed on a television set or similar monitor device.

OVERVIEW

Modern digital cable networks generally use CA systems that fully encrypt digital audio and video to make programming inaccessible except to those who have properly subscribed. Such encryption is designed to thwart hackers and non-subscribers from receiving programming that has not been paid for. However, as cable operators wish to provide their subscribers with set-top boxes from any of several manufacturers, they are frustrated by the need to transmit multiple copies of a single program encrypted with multiple encryption technologies compliant with the CA systems of each STB manufacturer.

This need to carry multiple copies of the programming (called "full dual carriage") uses up valuable bandwidth that could be used to provide the viewer with additional programming content. Certain embodiments of the present invention address this problem in which the bandwidth requirements to provide an equivalent to multiple carriage are minimized. The result could be described as "Virtual Dual Carriage" since the benefits of full dual carriage are provided without the full bandwidth cost. Several embodiments of the present invention are presented herein to accomplish effective partial scrambling. These embodiments vary by the criteria used to select the portion to encrypt. The portion selected in turn affects the additional bandwidth requirements and the effectiveness of the encryption. It may be desirable to use one encryption process or several processes in combination in a manner consistent with embodiments of the present invention.

Certain of the implementations of partial dual encryption described herein utilize an additional (secondary) PID for each duplicated component. These secondary PIDs are used to tag packets that carry duplicated content with an additional encryption method. The PSI is enhanced to convey information about the existence these new PIDs in such a way that inserted PIDs are ignored by legacy STBs but can be easily extracted by new STBs.

Some implementations of partial dual encryption involve duplicating only certain packets tagged with a given PID. Methods for selecting which packets to encrypt are detailed hereinafter. The original (i.e. legacy) PID continues to tag the

1 packets encrypted with legacy encryption as well as other packets sent in the clear.
2 The new PID is used to tag packets encrypted by the second encryption method.
3 packets with the secondary PID shadow the encrypted packets tagged with the
4 primary PID. The packets making up the encrypted pairs can occur in either order
5 but, in the preferred implementation, maintain sequence with the clear portion of
6 the PID stream. By use of the primary and secondary PIDs, the decoder located
7 in the set-top box can readily determine which packets are to be decrypted using
8 the decryption method associated with that set-top box, as will be clear upon
9 consideration of the following description. The processes used to manipulate PIDs
10 will be described later in greater detail.

11 The encryption techniques described herein can be broadly categorized
12 (according to one categorization) into three basic variations - encrypting just a
13 major portion (i.e. audio), encrypting just the SI, and encrypting just selected
14 packets. In general, each of the encryption techniques used in the embodiments
15 disclosed herein seek to encrypt portions of the an A/V signal or associated
16 information while leaving other portions of the A/V signal in the clear to conserve
17 bandwidth. Bandwidth can be conserved because the same clear portion can be
18 sent to all varieties of set-top boxes. Various methods are used to select the
19 portions of information to be encrypted. By so doing, the various embodiments of
20 this invention eliminate the traditional "brute-force" technique of encrypting the
21 entire content in one specific scrambling scheme, which predicates the redundant
22 use of bandwidth if alternate scrambling schemes are desired. In addition, each
23 of the partial dual encryption schemes described herein can be used as a single
24 partial encryption scheme without departing from embodiments of the present
25 invention.

26 The various embodiments of the invention use several processes, alone or
27 in combination, to send substantial portions of content in the clear while encrypting
28 only a small amount of information required to correctly reproduce the content.
29 Therefore the amount of information transmitted that is uniquely encrypted in a
30 particular scrambling scheme is a small percentage of the content, as opposed to

1 the entire replication of each desired program stream. For purposes of the
2 exemplary systems in this document, encryption system A will be considered the
3 legacy system throughout. Each of the several encryption techniques described
4 above will now be described in detail.

5 The various embodiments of the invention allow each participating CA
6 system to be operated independently. Each is orthogonal to the other. Key sharing
7 in the headend is not required since each system encrypts its own patents.
8 Different key epochs may be used by each CA system. For example, packets
9 encrypted with Motorola's proprietary encryption can use fast changing encryption
10 keys using the embedded security ASIC, while packets encrypted with NDS' smart
11 card based system use slightly slower changing keys. This embodiment works
12 equally well for Scientific Atlanta and Motorola legacy encryption.

13

14 **ENCRYPTED ELEMENTARY STREAM**

15 Turning now to **FIGURE 2**, one embodiment of a system that reduces the
16 need for additional bandwidth to provide multiple carriage is illustrated as system
17 100. In this embodiment, the system takes advantage of the fact that viewing
18 television programming without audio is usually undesirable. While there are
19 exceptions (e.g., adult programming, some sporting events, etc.), the typical viewer
20 is unlikely to accept routine viewing of television programming without being able
21 to hear the audio. Thus, at headend 122, the video signal 104 is provided in the
22 clear (unencrypted) while the clear audio 106 is provided to multiple CA systems
23 for broadcast over the cable network. In the exemplary system 100, clear audio
24 106 is provided to an encryption system 118 that encrypts audio data using
25 encryption system A (encryption system A will be considered the legacy system
26 throughout this document). Simultaneously, clear audio 106 is provided to
27 encryption system 124 that encrypts the audio data using encryption system B.
28 Clear video is then multiplexed along with encrypted audio from 118 (Audio A) and
29 encrypted audio from 124 (Audio B), system information 128 and program specific
30 information 129.

1 After distribution through the cable system 32, the video, system information,
2 program specific information, Audio A and Audio B are all delivered to set-top
3 boxes 36 and 136. At legacy STB 36, the video is displayed and the encrypted
4 audio is decrypted at CA system A 40 for play on television set 44. Similarly, at
5 new STB 136, the video is displayed and the encrypted audio is decrypted at CA
6 system B 140 for play on television set 144.

7 Audio has a relatively low bandwidth requirement compared with a complete
8 A/V program (or even just the video portion). The current maximum bit rate for
9 stereophonic audio at 384 Kb/second is approximately 10% of a 3.8Mb/second
10 television program. Thus, for dual carriage of only encrypted audio (with video
11 transmitted in the clear) in a system with ten channels carried with 256 QAM
12 (quadrature amplitude modulation), a loss of only about one channel worth of
13 bandwidth would occur. Therefore, approximately nine channels could be carried.
14 This is a dramatic improvement over the need to dual encrypt all channels, which
15 would result in a decrease in available channels from ten to five. Where deemed
16 necessary, e.g., sporting events, pay per view, adult programming, etc., dual
17 encryption of both audio and video can still be carried out, if desired.

18 Both legacy and new set-top boxes can function in a normal manner
19 receiving video in the clear and decrypting the audio in the same manner used for
20 fully decrypting encrypted A/V content. If the user has not subscribed to the
21 programming encrypted according to the above scheme, at best the user can only
22 view the video without an ability to hear the audio. For enhanced security over the
23 video, it possible to employ other embodiments of the invention (as will be
24 described later) here as well. (For example, the SI may be scrambled to make it
25 more difficult for a non-authorized set-top box to tune to the video portion of the
26 program.) Unauthorized set-top boxes that have not been modified by a hacker, will
27 blank the video as a result of receipt of the encrypted audio.

28 Authorized set-top boxes receive Entitlement Control Messages (ECM) that
29 are used to get access criteria and descrambling keys. The set-top box attempts
30 to apply the keys to video as well as the audio. Since the video is not scrambled,

1 it simply passes through the set-top boxes' descrambler unaffected. The set-top
2 boxes do not care that the video is in-the-clear. The un-modified and un-subscribed
3 set-top boxes behave as being un-authorized for the scrambled audio as well as the
4 clear video. The video, as well as the audio which was actually scrambled, will be
5 blanked. An on-screen display may appear on the TV stating that the viewer needs
6 to subscribe to programming. This desirably totally inhibits the casual viewer from
7 both hearing and viewing the content.

8 In one embodiment of the present invention, the encrypted audio is
9 transmitted as digitized packets over the A/V channel. Two (or more) audio
10 streams are transmitted encrypted according to the two (or more) encryption
11 systems in use by the system's set-top boxes. In order for the two (or more) STBs
12 to properly decrypt and decode their respective audio streams, SI (system
13 information) data are transmitted from the cable system's headend 122 that
14 identifies the particular channel where the audio can be found using a transmitted
15 Service Identifier to locate the audio. This is accomplished by assigning the audio
16 for system A a first packet identifier (PID) and assigning the audio for system B
17 a second packet identifier (PID). By way of example, and not limitation, the
18 following program specific information (PSI) can be sent to identify the location of
19 the audio for two systems, one using NDS conditional access and one using
20 Motorola conditional access. Those skilled in the art will understand how to adapt
21 this information to the other embodiments of partial encryption described later
22 herein.

23 The SI can be separately delivered to both legacy and non-legacy set-top
24 boxes. It is possible to send SI information so that the legacy and non-legacy set-
25 top boxes operate essentially without interference. In the SI delivered to legacy set-
26 top boxes, the VCT (virtual channel table) would state that the desired program, e.g.
27 HBO referenced as program number 1, is on Service ID "1" and that the VCT
28 access control bit is set. The network information table (NIT) delivered to that first
29 STB would indicate that Service ID "1" is at frequency = 1234. In the SI delivered
30 to non-legacy set-top boxes, the VCT would state that the desired program, e.g.

1 HBO referenced as program number 1001, is on Service ID "1001" and that the
2 VCT access control bit is set. The network information table delivered to the non-
3 legacy STB would indicate that the Service ID "1001" is at frequency 1234. The
4 following exemplary program association Table PSI data are sent to both legacy
5 and non-legacy set-top boxes (in MPEG data structure format):
6
7

1
2 PAT sent on PID=0x0000

3
4 PAT 0x0000
5 - Transport Stream ID
6 - PAT version
7 - Program Number 1
8 - PMT 0x0010
9 - Program Number 2
10 - PMT 0x0020
11 - Program Number 3
12 - PMT 0x0030
13 - Program Number 4
14 - PMT 0x0040
15 - Program Number 5
16 - PMT 0x0050
17 - Program Number 6
18 - PMT 0x0060
19 - Program Number 7
20 - PMT 0x0070
21 - Program Number 8
22 - PMT 0x0080
23 - Program Number 9
24 - PMT 0x0090
25 - Program Number 1001
26 - PMT 0x1010
27 - Program Number 1002
28 - PMT 0x1020
29 - Program Number 1003
30 - PMT 0x1030
31 - Program Number 1004
32 - PMT 0x1040
33 - Program Number 1005
34 - PMT 0x1050
35 - Program Number 1006
36 - PMT 0x1060
37 - Program Number 1007
38 - PMT 0x1070
39 - Program Number 1008
40 - PMT 0x1080
41 - Program Number 1009
42 - PMT 0x1090

43 The following exemplary program map table PSI data are selectively
44 received by legacy and non-legacy set-top boxes (in MPEG data structure format):

PMT sent on PID=0x0010

PMT 0x0010

- PMT Program number 1
- PMT Section Version 10
- PCR PID 0x0011
- Elementary Stream
 - Stream Type (Video 0x02 or 0x80)
 - Elementary PID (0x0011)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #1
- Elementary Stream
 - Stream Type (Audio 0x81)
 - Elementary PID (0x0012)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #1

PMT sent on PID=0x1010

PMT 0x1010

- PMT Program number 1010
- PMT Section Version 10
- PCR PID 0x0011
- Elementary Stream
 - Stream Type (Video 0x02 or 0x80)
 - Elementary PID (0x0011)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #2
- Elementary Stream
 - Stream Type (Audio 0x81)
 - Elementary PID (0x0013)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #2

Considering an example wherein it is desired to deliver programming in a

system using either Motorola or Scientific Atlanta as well as NDS CA, the above communications are consistent with the PSI delivered by both Motorola and Scientific Atlanta in their CA systems, with only minor changes. The program association table (PAT) is changed to reference an additional program map table (PMT) for each program. Each program in this embodiment has two program numbers in the PAT. In the table above, program number 1 and program number 1001 are the same program except that they will reference different audio PIDs and

1 CA descriptors. Changes in the system to create multiple PMTs and to multiplex
2 new PAT and PMT information with the data stream can be made to appropriately
3 modify the cable system headend equipment. Again, those skilled in the art will
4 understand how to adapt these messages to other partial encryption schemes
5 described herein. An advantage of this approach is that no special hardware or
6 software is required for headend or for legacy and non-legacy set-top boxes to
7 deliver audio that is both legacy and non-legacy encrypted using this scheme.

8 This technique deters the user from use of premium programming which has
9 not been paid for by rendering it inaudible, but a hacker may attempt to tune the
10 video. To combat this, the mechanisms employed in other encryption techniques
11 consistent with the present invention (as will be described later) can be employed
12 simultaneously, if desired. Since closed captioning is generally transmitted as a
13 part of the video data, the user can still obtain readable audio information in
14 conjunction with clear video. Thus, although adequate for some applications, the
15 present technique alone may not provide adequate protection in all scenarios. In
16 another embodiment, video packets containing closed captioning information as
17 a part of the payload can additionally be scrambled.

18 In an alternative embodiment, only the video may be dual encrypted with
19 separate PIDs assigned to each set of encrypted video. While this may provide a
20 more secure encryption for general programming (since video may be more
21 important than audio), the amount of bandwidth savings compared with full dual
22 carriage is only approximately ten percent, since only the audio is shared amongst
23 all the set-top boxes. However, this approach might be used for certain content,
24 e.g. adult and sports, and help reduce the bandwidth overhead for that content
25 while the audio encryption approach may be used for other content types. In the
26 Digital Satellite Service (DSS) transport standard used for the DirecTV™ service,
27 the audio packets can be identified for encryption by use of the service channel
28 identifier (SCID) which is considered equivalent.

1 **TIME SLICING**

2 Another embodiment consistent with the present invention is referred to
3 herein as time slicing and is illustrated in **FIGURE 3** as system 200. In this
4 embodiment, a portion of each program is encrypted on a time dependent basis in
5 a manner that disrupts viewing of the program unless the user has paid for the
6 programming. This embodiment of the invention can be implemented as partially
7 encrypted video and clear audio, clear video and partially encrypted audio or
8 partially encrypted video and audio. The duration of the time slice that is encrypted,
9 taken as a percentage of the total time, can be selected to meet any suitable
10 desired balance of bandwidth usage, security against hackers. In general, under
11 any of the embodiments described herein, less than 100 percent of the content is
12 encrypted to produce a desired partial encryption. . The following example details
13 partially encrypted video and audio.

14 By way of example, and not limitation, consider a system which has nine
15 programs that are to be dual partially encrypted according to the present exemplary
16 embodiment. These nine channels are fed to the cable headend as a multiplexed
17 stream of packets and are digitally encoded using packet identifiers (PID) to identify
18 packets associated with a particular one of the nine programs. In this example,
19 assume that those nine programs have video PIDs numbered 101-109 and audio
20 PIDs numbered 201-209. The partial encryption, according to this embodiment is
21 time multiplexed among the programs so that only packets from a single program
22 are encrypted at any given time. The method does not need to be content aware.

23 With reference to **TABLE 1** below, an exemplary embodiment of a time slice
24 dual encryption scheme consistent with an embodiment of the invention is
25 illustrated. For program 1 having primary video PID 101 and primary audio PID 201,
26 during the first time period, packets having PID 101 and PID201 are encrypted
27 using encryption system A, while the others representing the other programs are
28 sent in the clear. In this embodiment, secondary PIDs are also assigned to both
29 the video and the audio. The secondary PIDs are PID 111 for video and PID 211 for

1 audio respectively for program 1. The packets with the secondary PIDs are
2 encrypted using encryption system B during the first time period. The next eight
3 time periods are sent in the clear. Then for time period 10, packets having any of
4 the above four PIDs are again encrypted followed by the next eight time periods
5 being sent in the clear. In a similar manner, during the second period of program
6 2 having primary video PID 102 and primary audio PID 201 are encrypted using
7 encryption system A and packets with their associated secondary PIDs are
8 encrypted using encryption system B, and during the next eight time periods are
9 sent in the clear, and so on. This pattern can be seen clearly in **TABLE 1** by
10 examination of the first nine rows. Both audio and video packets, or audio
11 alone or video alone can be encrypted according to this technique, without
12 departing from the invention. Also, the audio and video can have their own
13 individual encryption sequence. In **TABLE 1**, P1 indicates time period number 1,
14 P2 indicated time period number 2 and so on. EA indicates that the information is
15 encrypted using CA system A and EB indicates that the information is encrypted
16 using CA encryption system B.
17

1	PROG.	VIDEO PID	AUDIO PID	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	...
2	1	PID 101	PID 201	EA	clear	EA	clear	clear	...							
3	2	PID 102	PID 202	clear	EA	clear	EA	clear	...							
4	3	PID 103	PID 203	clear	clear	EA	clear	EA	...							
5	4	PID 104	PID 204	clear	clear	clear	EA	clear	...							
6	5	PID 105	PID 205	clear	clear	clear	clear	EA	clear	...						
7	6	PID 106	PID 206	clear	clear	clear	clear	clear	EA	clear	clear	clear	clear	clear	clear	...
8	7	PID 107	PID 207	clear	clear	clear	clear	clear	clear	EA	clear	clear	clear	clear	clear	...
9	8	PID 108	PID 208	clear	EA	clear	clear	clear	clear	...						
10	9	PID 109	PID 209	clear	EA	clear	clear	clear	...							
11	1	PID 111	PID 211	EB									EB			...
12	2	PID 112	PID 212		EB									EB		...
13	3	PID 113	PID 213			EB								EB		...
14	4	PID 114	PID 214				EB									...
15	5	PID 115	PID 215					EB								...
16	6	PID 116	PID 216						EB							...
17	7	PID 117	PID 217							EB						...
18	8	PID 118	PID 218								EB					...
19	9	PID 119	PID 219									EB				...

TABLE 1

In order to retain compatibility with an established legacy encryption system (encryption system A), the encrypted periods for each of programs one through nine are encrypted using encryption system A. Legacy STB equipment will accept such partially encrypted A/V data streams passing unencrypted packets and decrypting encrypted packets transparently. However, it is desired to obtain dual encryption using both encryption system A and encryption system B. In order to achieve this, a specified program is assigned both primary PIDs (e.g., for program 1, video PID 101 and audio PID 201) and a secondary PID (e.g., for program 1, video PID 111 and audio PID 211) to carry the elementary data streams for a given premium channel.

With reference to **FIGURE 3**, system 200 generally depicts the functionality of the cable system headend 222 wherein N channels of clear video 204 at the headend 222 are provided to an intelligent switch 216 (operating under control of a programmed processor) which routes packets that are to be transmitted in the clear to be assigned a primary PID at 220. Packets that are to be encrypted are

routed to both conditional access system A encrypter 218 and to conditional access system B encrypter 224. Once encrypted, these encrypted packets from 218 and 224 are assigned primary or secondary PIDs respectively at 220. System information from 228 is multiplexed or combined with the clear packets, the system A encrypted packets and the system B encrypted packets and broadcast over the cable system 32.

For discussion purposes, if the period of the time slice is 100 milli-seconds, then as shown in **TABLE 1**, there are on average one and a fraction encrypted periods totaling 111 milli-seconds each second for all nine-programs. If the period is 50 milli-seconds, then there are on average two and a fraction encrypted periods totaling 111 milli-seconds. A non-subscribing box attempting to tune video would obtain a very poor image if it could maintain any sort of image lock and the audio would be garbled.

The PSI for a partially scrambled stream is handled slightly differently from the dual audio encryption example above. Essentially, the same SI and PAT PSI information can be sent to both legacy and non-legacy set-top boxes. The difference lies with the PMT PSI information. The legacy set-top box parses the PMT PSI and obtains the primary video and audio PIDs as before. The non-legacy set-top box obtains the primary PIDs like the legacy set-top box but must look at the CA descriptors in the PMT PSI to see if the stream is partially scrambled. The secondary PID is scrambled specifically for a particular CA provider, consequently it makes sense to use the CA descriptor specific to a particular CA provider to signal that PID. The invention can allow more than two CA providers to co-exist by allowing more than one secondary PID. The secondary PID shall be unique to a particular CA provider. The set-top box knows the CA ID for the CA it has, and can check all CA descriptors for the relevant one for it.

While it is possible to send the secondary PID data as private data in the same CA descriptor used for the ECM, the preferred embodiment uses separate CA descriptors. The secondary PID is placed in the CA PID field. This allows headend processing equipment to "see" the PID without having to parse the private

1 data field of the CA descriptor. To tell the difference between the ECM and
2 secondary PID CA descriptor, a dummy private data value can be sent.
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5 **PMT sent on PID=0x0010**

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- PMT Program number 1
- PMT Section Version 10
- PCR PID 0x0011
- Elementary Stream
 - Stream Type (Video 0x02 or 0x80)
 - Elementary PID (0x0011)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #1
 - CA Descriptor (ECM) for CA provider #2
 - CA Descriptor (Secondary PID) for CA provider #2
- Elementary Stream
 - Stream Type (Audio 0x81)
 - Elementary PID (0x0012)
 - Descriptor
 - CA Descriptor (ECM) for CA provider #1
 - CA Descriptor (ECM) for CA provider #2
 - CA Descriptor (Secondary PID) for CA provider #2

38 **CA Descriptor for CA Provider #2 (ECM)**

39 **Descriptor**

- Tag: Conditional Access (0x09)
- Length: 4 Bytes
- Data
 - CA System ID: 0x0942 (2nd CA provider)
 - CA PID (0x0015)

40 **CA Descriptor for CA Provider #2 (Secondary PID)**

41 **Descriptor**

- Tag: Conditional Access (0x09)
- Length: 5 Bytes
- Data
 - CA System ID: 0x1234 (2nd CA provider)
 - CA PID (0x0016)
 - Private Data

1
2 Legacy STB 36 operating under CA system A receives the data, ignores
3 the secondary PIDs, decrypts the packets encrypted under CA system A and
4 presents the program to the television set 44. New or non-legacy STB 236
5 receives the SI 228. It receives PSI 229 and uses the PMT to identify the
6 primary and secondary PID, called out in the second CA descriptor, associated
7 with the program being viewed. The packets encrypted under CA system A are
8 discarded and the packets encrypted under CA system B with the secondary
9 PID are decrypted by CA system B 240 and inserted into the clear data stream
10 for decoding and display on television set 244.

11 **FIGURE 4** illustrates one process for encoding at the cable system headend
12 that can be used to implement an embodiment of the present invention wherein CA
13 system A is the legacy system and CA system B is the new system to be
14 introduced. As a clear packet is received, at 250 for a given program, if the packet
15 (or frame) is not to be encrypted (i.e., it is not the current time slice for encryption
16 for this program), the clear packet (C) is passed on to be inserted into the output
17 stream at 254. If the current packet is to be encrypted by virtue of the current
18 packet being a part of the encryption time slice, the packet is passed for encryption
19 to both packet encryption process A 258 and packet encryption process B 262.
20 The encrypted packets from encryption process A at 258 (EA) are passed on to 254
21 for insertion into the output stream. The encrypted packets from encryption
22 process B at 262 (EB) are assigned a secondary PID at 264 for insertion into the
23 output stream at 254. This is repeated for all packets in the program.

24 **FIGURE 5** illustrates a process used in the STB 236 having the newly
25 introduced CA system B for decrypting and decoding the received data stream
26 containing C, EA and EB packets having primary and secondary PIDs as
27 described. When a packet is received at 272, it is inspected to see if it has a the
28 primary PID of interest. If not, the packet is examined to see if it has the secondary
29 PID of interest at 274. If the packet has neither the primary or secondary PID, it is

1 ignored or dropped at 278. Any intervening packets between the EA and EB
2 packets that are not the primary or secondary PID are discarded. It is an
3 implementation and mainly a buffering issue whether a decoder can receive
4 multiple EA or EB in a row before receiving the replacement matched EA or EB
5 packet. Also, just as easy to detect for secondary packets that come before and
6 not after the primary packet. It is also possible to design a circuit where either
7 case can happen – the secondary packet can before or after the primary packet.
8 If the packet has the primary PID of interest, the packet is examined at 284 to
9 determine if it is encrypted. If not, the packet (C) is passed directly to the decoder
10 at 288 for decoding. If the packet is encrypted at 284, it is deemed to be an EA
11 packet and is dropped or ignored at 278. In some implementations, the primary
12 packet's encryption does not get checked at 284. Rather, its simple position
13 relative to the secondary packet can be checked at 284 to identify it for
14 replacement.

15 If the packet has the secondary PID at 274, the PID is remapped to the
16 primary PID at 292 (or equivalently, the primary PID is remapped to the secondary
17 PID value). The packet is then decrypted at 296 and sent to the packet decoder at
18 288 for decoding. Of course, those skilled in the art will recognize that many
19 variations are possible without departing from the invention, for example, the order
20 of 292 and 296 or the order of 272 and 274 can be reversed. As mentioned earlier,
21 284 can be replaced with a check of primary packet position with respect to the
22 secondary packet. Other variations will occur to those skilled in the art.

23 Legacy STB 36 operating under the encryption system A totally ignores the
24 secondary PID packets. Packets with the primary PID are decrypted, if necessary,
25 and passed to the decoder without decryption if they are clear packets. Thus, a so
26 called "legacy" STB operating under encryption system A will properly decrypt and
27 decode the partially encrypted data stream associated with the primary PID and
28 ignore the secondary PID without modification. STBs operating under the
29 encryption system B are programmed to ignore all encrypted packets associated

1 with the primary PID and to use the encrypted packets transmitted with the
2 secondary PID associated with a particular channel.

3 Thus, each dual partially encrypted program has two sets of PIDs associated
4 therewith. If, as described, the encryption is carried out on a period-by-period
5 basis, for the system shown with an appropriate time slice interval, the picture will
6 be essentially unviewable on a STB with neither decryption.

7 In order to implement this system in the headend 322 of **FIGURE 6**, the SI
8 and PSI can be modified for inclusion of a second set of CA descriptor information.
9 Legacy set-top boxes may not be able to tolerate unknown CA descriptors.
10 Consequently, alternatively, in the set-top box, it may be possible to "hard code"
11 offsets from the legacy CA PIDs for both the content PIDs and/or the SI/PSI and
12 ECM PIDs. Alternatively, parallel PSI may be sent. For example, an auxiliary PAT
13 can be delivered on PID 1000 instead of PID 0 for the non-legacy set-top boxes. It
14 can reference auxiliary PMTs not found in the legacy PAT. The auxiliary PMTs can
15 contain the non-legacy CA descriptors. Since auxiliary PMTs would not be known
16 to the legacy set-top boxes, there would not be any interoperation issue.

17 In systems where system A corresponds to legacy set-top boxes
18 manufactured by Motorola or Scientific Atlanta, no modifications to the STBs are
19 required. For the system B compliant STBs, for dual carriage of partially encrypted
20 programs as described herein, the video and audio decoder are adapted to listen
21 to two PIDs each (a primary and a secondary PID) instead of just one. There may
22 be one or more secondary shadow PIDs, depending on the number of non-legacy
23 CA systems in use, however a specific set-top box only listens to one of the
24 secondary PIDs as appropriate for the CA method being used by that specific STB.
25 In addition, ideally the encrypted packets from the PID carrying the mostly clear
26 video or audio are ignored. Since ignoring "bad packets" (those that cannot be
27 readily decoded as is) may already be a function that many decoders perform, thus
28 requiring no modification. For systems with decoders that do not ignore bad
29 packets, a filtering function can be used. It should be understood that the time
30 slice encryption technique could be applied to just the video or the audio. Also, the

1 video may be time slice encrypted while the audio is dual encrypted as in the
2 earlier embodiment. The time slice technique may be applied to multiple programs
3 concurrently. The number of programs that encrypted during a period of time is
4 mainly an issue of bandwidth allocation, and although the example discusses
5 scrambling a single program at a time, the invention is not limited by that. Other
6 combinations of encryption techniques described in this document will also occur
7 to those skilled in the art.

8

9

10 **Mth AND N PACKET ENCRYPTION**

11 Another embodiment consistent with the present invention is referred to
12 herein as Mth & N packet encryption. This is a variation of the embodiment
13 illustrated in **FIGURE 3** as system 200. In this embodiment, packets of each PID
14 representing a program are encrypted in a manner that disrupts viewing of the
15 program unless the user has paid for the programming. In this embodiment, M
16 represents the number of packets between the start of an encryption event. N
17 represents the number of packets that are encrypted in a row, once encryption
18 takes place. N is less than M. If M=9 and N=1, then every nine packets there is an
19 encryption event lasting 1 packet. If M=16 and N=2, then every sixteen packets
20 there is an encryption event lasting two packets. Each packet to be dual partially
21 encrypted is duplicated and processed using CA system A 218 and CA system B
22 as in the previous embodiment. The difference in operation between this
23 embodiment and the time slicing technique previously is in the operation of switch
24 216 to effect the selection of packets to encrypt under control of a programmed
25 processor.

26 By way of example, and not limitation, consider a system which has nine
27 channels of programming that are to be dual encrypted according to the present
28 exemplary embodiment. These nine channels are digitally encoded using packet
29 identifiers (PID) to identify packets associated with a particular one of nine
30 programs. In this example, assume that those nine programs have video PIDs

1 numbered 101-109 and audio PIDs numbered 201-209. The encryption, according
2 to this embodiment is random program-to-program so that packets from other
3 programs may be encrypted at the same time. This is illustrated in **TABLE 2** below
4 in which M=6 and N=2 and in which only video is encrypted, but this should not be
5 considered limiting. The method does not need to be content aware. In **TABLE 2**,
6 PK1 indicated packet number 1, PK2 indicates packet number 2, and so on.
7

PROG.	VIDEO	PK1	PK2	PK3	PK4	PK5	PK6	PK7	PK8	PK9	PK10	PK11	PK12	...
1	PID 101	EA	EA	clear	clear	clear	clear	EA	EA	clear	clear	clear	clear	..
2	PID 102	clear	clear	clear	EA	EA	clear	clear	clear	clear	EA	EA	clear	...
3	PID 103	clear	clear	EA	EA	clear	clear	clear	clear	EA	EA	clear	clear	...
4	PID 104	clear	clear	clear	EA	EA	clear	clear	clear	clear	EA	EA	clear	...
5	PID 105	clear	clear	EA	EA	clear	clear	clear	clear	EA	EA	clear	clear	...
6	PID 106	EA	clear	clear	clear	clear	EA	EA	clear	clear	clear	clear	EA	..
7	PID 107	EA	EA	clear	clear	clear	clear	EA	EA	clear	clear	clear	clear	...
8	PID 108	clear	EA	EA	clear	clear	clear	clear	EA	EA	clear	clear	clear	...
9	PID 109	EA	clear	clear	clear	clear	EA	EA	clear	clear	clear	clear	EA	...
1	PID 111	EB	EB					EB	EB					...
2	PID 112				EB	EB					EB	EB		...
3	PID 113			EB	EB					EB	EB			...
4	PID 114				EB	EB					EB	EB		...
5	PID 115			EB	EB					EB	EB			..
6	PID 116	EB					EB	EB					EB	..
7	PID 117	EB	EB					EB	EB					..
8	PID 118		EB	EB					EB	EB				...
9	PID 19	EB					EB	EB					EB	...

27 **TABLE 2**

28
29 In the example of **TABLE 2**, each program is encrypted fully independently
30 of the others using the M=6 and N=2 encryption scheme. Again, the illustrated
31 example encrypts only the video, but audio could also be encrypted according to

1 this or another arrangement. If applied to just the video, audio may be dual
2 scrambled or time slice encrypted as in earlier embodiments. Alternatively, if
3 applied to just the audio, the video may be time sliced as in the earlier
4 embodiment.

5 Those skilled in the art will recognize that many variations of the technique
6 can be devised consistent with the partial scrambling concepts disclosed herein.
7 For example, a pattern of five clear followed by two encrypted followed by two clear
8 followed by one encrypted (CCCCCEECCECCCCEECCE...) is consistent with
9 variations of the present partial encryption concept, as are random, pseudo-random
10 and semi-random values for M and N may be used for selection of packets to
11 encrypt. Random, pseudo-random or semi-random (herein collectively referred to
12 as "random" herein) selection of packets can make it difficult for a hacker to
13 algorithmically reconstruct packets in a post processing attempt to recover
14 recorded scrambled content. Those skilled in the art will understand how to adapt
15 this information to the other embodiments of partial encryption described later
16 herein. Some of the embodiments can be used in combination to more effectively
17 secure the content.

19 **DATA STRUCTURE ENCRYPTION**

20 Another partial encryption method consistent with embodiments of the
21 present invention uses a data structure as a basis for encryption. By way of
22 example and not limitation, one convenient data structure to use for encryption is
23 an MPEG video frame. This is illustrated (again with video only) in **TABLE 3** below
24 in which every tenth video frame is encrypted. In this embodiment, each program's
25 ten frame encryption cycle is distinct from each other channel, but this should not
26 be considered limiting. This concept can be viewed as a variation of the time slice
27 or Mth and N partial encryption arrangement (or other pattern) based upon video or
28 audio frames (or some other data structure) with the exemplary embodiment having
29 M=10 and N=1. Of course, other values of M and N can be used in a similar

1 embodiment. In **TABLE 3**, F1 represents frame number 1, F2 represents frame
2 number 2 and so on.
3

4	PROG.	VIDEO	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	...
5	1	PID 101	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	EA	clear	...
6	2	PID 102	clear	clear	clear	EA	clear	clear	clear	clear	clear	clear	clear	clear	...
7	3	PID 103	clear	clear	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	...
8	4	PID 104	clear	clear	clear	clear	EA	clear	clear	clear	clear	clear	clear	clear	...
9	5	PID 105	clear	clear	clear	EA	clear	clear	clear	clear	clear	clear	clear	clear	...
10	6	PID 106	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	EA	clear	...
11	7	PID 107	clear	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	EA	...
12	8	PID 108	clear	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	EA	...
13	9	PID 109	EA	clear	clear	clear	clear	clear	clear	clear	clear	clear	EA	clear	...
14	1	PID 111	EB										EB		
15	2	PID 112				EB									..
16	3	PID 113			EB										...
17	4	PID 114				EB									...
18	5	PID 115				EB									...
19	6	PID 116	EB										EB		...
20	7	PID 117		EB										EB	...
21	8	PID 118		EB										EB	...
22	9	PID 119	EB										EB		...

23 **TABLE 3**

24
25 Thus, again each encrypted program has two sets of PIDs associated
26 therewith. If, as described, the encryption is carried out on a period-by-period
27 basis, for the system shown, the picture will be essentially unviewable. For a nine
28 program system at 30 frames per second as depicted, approximately three frames
29 per second will be encrypted. For viewers who are not entitled to view the program,
30 their STB will be unable to capture much more than an occasional frozen frame as
31 the STB constantly attempts to synchronize and recover. Viewers who have

1 subscribed to the programming will be able to readily view the programming. The
2 bandwidth cost for such an encryption arrangement depends upon the frequency
3 with which the encryption is applied. In the above example, an extra factor of 1/9
4 of data are transmitted for each program. In this example, approximately one
5 program's worth of bandwidth is used. With a greater number of programs, fewer
6 packets per program are encrypted and the security of the encryption system may
7 degrade somewhat. As in the randomized M and N method, random frames may
8 be selected. Choosing random frames, in the video case, would help guarantee
9 that all frame types would be affected – intra-coded frames (I frames), predictive-
10 coded (P frames), Bi-directional-coded (B frames) and DC frames.

11 In a variation of the invention, it may be possible to encrypt fewer packets to
12 achieve an acceptable level of security. That is, perhaps in a system of nine
13 programs, only one frame per second may need to be encrypted to achieve
14 acceptable levels of security. In such a system, the overhead becomes one
15 encrypted period per second per program or approximately 1/30 of data transmitted
16 in overhead. This level of overhead is a dramatic improvement over the 50% loss
17 of bandwidth associated with full dual carriage of encryption under two encryption
18 systems. In another variation of the invention, it may be possible to encrypt only
19 certain video frames to achieve an acceptable level of security. For example, for
20 MPEG content, only intra-coded frames (I frames) may be scrambled to further
21 reduce the bandwidth overhead and still maintain an acceptable level of security.
22 These offer significant improvement over the bandwidth required for full dual
23 carriage.

24

25

26 **CRITICAL PACKET ENCRYPTION**

27 Substantial efficiency in bandwidth utilization can be achieved by use of a
28 selective packet-by-packet dual encryption technique. In this technique, packets
29 are selected for encryption based upon their importance to the proper decoding of
30 the audio and/or video of the program content. .

1 This embodiment can reduce the bandwidth requirement compared with full
2 dual carriage of encrypted content by only scrambling a small fraction of the
3 packets. Clear packets are shared between the two (or more) dual carriage PIDs.
4 In one preferred embodiment, as will be disclosed, less than about one percent of
5 the total content bandwidth is used. In a system with a legacy encryption scheme,
6 clear program content packets can be received by both legacy and new set-top
7 boxes. As mentioned before, encrypted packets are dual carried and processed
8 by the respective set-top boxes with the appropriate CA. Each CA system is
9 orthogonal. Key sharing is not required and different key epochs may be used by
10 each CA system. For example, a system with Motorola's proprietary encryption can
11 generate fast changing encryption keys using the embedded security ASIC, while
12 an NDS smart card based system can generate slightly slower changing keys.
13 This embodiment works equally well for Scientific Atlanta and Motorola legacy
14 encryption.

15 Referring now to **FIGURE 6**, a block diagram of a system consistent with an
16 embodiment of the present invention in which portions of programming are dual
17 encrypted on a packet-by-packet basis is illustrated as system 300. In this system,
18 packets of each program are dual encrypted using, for example, legacy CA system
19 A and CA system B. The packets that are encrypted are selected based upon their
20 importance to the proper decoding of the video and/or audio stream.

21 In the system illustrated in **FIGURE 6**, the cable system headend 322
22 selects A/V content 304 packets at a packet selector 316 for encryption. Packets
23 selected for encryption are chosen so that their non-receipt (by a non-paying
24 decoder) would severely affect the real-time decoding of a program, and any
25 possible post processing of recorded content. That is, only critical packets are
26 encrypted. For the video and audio, this can be accomplished by encrypting "start
27 of frame" transport stream packets containing PES (packetized elementary stream)
28 headers and other headers as part of the payload, since without this information,
29 the STB decoder cannot decompress the MPEG compressed data. MPEG2

1 streams identify "start of frame" packets with the "Packet Unit Start Indicator" in the
2 transport header. Generally, packets carrying a payload that contains a group of
3 pictures header or a video sequence header can be used to effect the present
4 scrambling technique.

5 MPEG (Moving Pictures Expert Group) compliant compressed video
6 repackages the elementary data stream into the transport stream in somewhat
7 arbitrary payloads of 188 bytes of data. As such, the transport stream packets
8 containing a PES header can be selected for encryption at selector 316 and dual
9 encrypted by both the CA system A encrypter 318 and the CA system B encrypter
10 324. Packets to be dual partially encrypted are duplicated and the PIDs of
11 duplicate packets encrypted by encrypter 324 are remapped at 330 to a secondary
12 PID as in the previous embodiment. The remaining packets are passed in the
13 clear. The clear packets, system A encrypted packets, system B encrypted
14 packets and system information 328 are multiplexed together for broadcast over the
15 cable system 32.

16 As with the previous system, the legacy STB 36 receives clear data and data
17 encrypted under CA encryption system A and transparently passes unencrypted
18 data combined with data decrypted by CA decryption A 40 to its decoder. In the
19 new STB 336, the program is assigned to both a primary and a secondary PID.
20 The clear packets with the primary PID are received and passed to the decoder.
21 The encrypted packets with the primary PID are discarded. Encrypted packets with
22 the secondary PID are decrypted and then recombined with the data stream (e.g.,
23 by remapping the packets to the primary PID) for decoding.

24 Using video is used as an example, each sample is known as a frame and
25 the sample rate is typically 30 frames per second. If the samples are encoded to
26 fit into 3.8 Mbps, each frame would occupy 127K bits of bandwidth. This data is
27 sliced for MPEG transport into packets of 188 bytes with the first packet(s) of each
28 frame containing the header used for instructions to process the body of the frame
29 data. Dual encrypting just the first header packet (1504 additional bits) requires

1 only 1.2% (1504/127K) of additional bandwidth. For high definition (19 Mbps)
2 streams the percentage is even less.

3 As previously stated, transport stream packets containing a PES header are
4 the preferred target for encryption according to the present embodiment. These
5 packets contain sequence headers, sequence extension headers, picture headers,
6 quantization and other decode tables that also fall within the same packet. If these
7 packets cannot be decoded (i.e., by a hacker attempting to view unauthorized
8 programming without paying the subscription charges), not even small portions of
9 the program can be viewed. In general, any attempt to tune to the program will
10 likely be met with a blank screen and no audio whatsoever since known decoder
11 integrated circuits use the PES header to sync up to an elementary stream such
12 as video and audio in real-time. By encrypting the PES header, the decoding
13 engine in an un-authorized set-top box cannot even get started. Post processing
14 attacks, e.g. on stored content, are thwarted by critical dynamically changing
15 information in the packet containing the PES header. Those skilled in the art will
16 appreciate that for implementation of this embodiment of the invention, other critical
17 or important packets or content elements may also be identified for encryption that
18 could severely inhibit unauthorized viewing without departing from the present
19 invention. For example, MPEG intra-coded or I frame picture packets could be
20 encrypted to inhibit viewing of the video portion of the program. Embodiments the
21 present invention may be used in any combination with other embodiments, e.g.
22 scrambling the packet containing the PES header as well as random, Mth and N,
23 or data structure encryption of the other packets. Critical packet encryption may
24 be applied to video encryption, while a different method may be applied to audio.
25 Audio could be dual encrypted, for instance. Other variations within the scope of
26 the present invention will occur to those skilled in the art.

27 **FIGURE 7** is a flow chart depicting an exemplary encoding process such as
28 that which would be used at headend 322 of **FIGURE 6**. When a transport stream
29 packet is received at 350, the packet is examined to determine if it meets a

1 selection criteria for encryption. In the preferred embodiment, this selection criteria
2 is the presence of a PES header as a portion of the packet payload. If not, the
3 packet is passed as a clear unencrypted packet (C) for insertion into the output
4 data stream at 354. If the packet meets the criteria, it is encrypted under CA
5 encryption system A at 358 to produce an encrypted packet EA. The packet is
6 also duplicated and encrypted under CA encryption system B at 362 to produce
7 an encrypted packet. This encrypted packet is mapped to a secondary PID at 366
8 to produce an encrypted packet EB. Encrypted packets EA and EB are inserted
9 into the output data stream along with clear packets C at 354. Preferably, the EA
10 and EB packets are inserted at the location in the data stream where the single
11 original packet was obtained for encryption so that the sequencing of the data
12 remains essentially the same.

13 When the output data stream from 354 is received at an STB compliant with
14 CA encryption system B such as 336 of **FIGURE 6**, a process such as that of
15 **FIGURE 8** (which is similar to that of **FIGURE 5**) can be utilized to decrypt and
16 decode the program. When a packet is received having either the primary or the
17 secondary PID at 370, a determination is made as to whether the packet is clear
18 (C) or encrypted under system A (EA) at 370 or encrypted under system B (EB) at
19 374. If the packet is clear, it is passed directly to the decoder 378. In some
20 embodiments, the relative position of the primary packet, before or after, to the
21 secondary packet may be used to signal a primary packet for replacement in the
22 stream. A check of the scrambling state of the primary packet is not specifically
23 required. If the packet is an EA packet, it is dropped at 380. If the packet is an EB
24 packet, it is decrypted at 384. At this point, the secondary PID packets and/or the
25 primary PID packets are remapped to the same PID at 388. The decrypted and
26 clear packets are decoded at 378.

27 The dual partial encryption arrangement described above can greatly reduce
28 the bandwidth requirements over that required for full dual carriage. Encrypting the
29 PES header information can be effective in securing video and audio content, while

1 allowing two or more CA systems to independently "co-exist" on the same cable
2 system. Legacy system A set-top boxes are un-affected, and system B set-top
3 boxes require only a minor hardware, firmware, or software enhancement to listen
4 for two PIDs each for video and audio. Each type of STB, legacy and non-legacy,
5 retains its intrinsic CA methodology. Headend modification is limited to selecting
6 content for encryption, introducing the second encrypter, and providing a means to
7 mix the combination into a composite output stream.

8 In one embodiment, the headend equipment is configured to
9 opportunistically scramble as much of the content as the bandwidth will allow, and
10 not just the critical PES headers. These additional scrambled packets would be
11 either in the PES payload or other packets throughout the video/audio frame to
12 provide even further security of the content.

13

14 **SI ENCRYPTION**

15 Turning now to **FIGURE 9**, one embodiment of a system that minimizes
16 the need for any additional bandwidth is illustrated as system 400. In this
17 embodiment, the system takes advantage of the fact that system information (SI)
18 428 is required for a set-top box to tune programming. In a cable system, SI is sent
19 in the out-of-band, a frequency set aside from the normal viewing channels. It is
20 possible to also sent it in-band. If sent in-band, the SI 428 is replicated and sent
21 with each stream. For discussion purposes, assume that the SI delivered to
22 "legacy" set-top boxes from previous manufacturers is separate from the SI
23 delivered to set-tops from new manufacturers such as STB 436. Consequently,
24 each version of the SI can be independently scrambled as illustrated using
25 conditional access system A 418 and conditional access system B 424. The clear
26 video 404 and clear audio 406 are delivered in the clear, but in order to understand
27 how to find them, the SI information 428 is needed.

28 The SI delivers information about channel names and program guide
29 information such as program names and start times, etc. ... as well as the
30 frequency tuning information for each channel. Digital channels are multiplexed

1 together and delivered at particular frequencies. In the embodiment of the
2 invention, the SI information is encrypted, and only made available to authorized
3 set-top boxes. If the SI information is not received to allow knowledge of the
4 location of all the A/V frequencies in the plant, then tuning cannot take place.

5 To frustrate a hacker who might program a set-top box to trial or scan
6 frequencies, the frequencies for the channels can be offset from the standard
7 frequencies. Also, the frequencies can be dynamically changed on a daily, weekly
8 or other periodic or random basis. A typical cable headend may have roughly 30
9 frequencies in use. Each frequency is typically chosen to avoid interference
10 between, among other things, each other, terrestrial broadcast signals, and
11 frequencies used by clocks of the receiving equipment. Each channel has at least
12 1 independent alternate frequency that if used would not could not cause
13 interference, or cause the frequency of adjoining channels to be changed. The
14 actual possible frequency maps are therefore 2^{30} or 1.07×10^9 . However, a hacker
15 might simply quickly try both frequencies on each tune attempt for each of the 30
16 channels or so. If successful in locating a frequency with content, the hacker's set-
17 top box can then parse the PSI 429 to learn about the individual PIDs that make up
18 a program. The hacker will have difficulty learning that "program 1" is "CNN", and
19 that "program 5" is "TNN", and so on. That information is sent with the SI, which as
20 stated above is scrambled and otherwise unavailable to the un-authorized set-top
21 box. However, a persistent hacker might yet figure those out by selecting each one
22 and examining the content delivered. So in order to frustrate the identification of
23 channels, the assignment of a program within a single stream can move around,
24 e.g. program 2 and program 5 swapped in the example above so that "program 1"
25 is "TNN" and "program 5" is "CNN". Also, it is possible to move programs to
26 entirely different streams with entirely new program groupings. A typical digital
27 cable headend can deliver 250 programs of content including music. Each can be
28 uniquely tuned. The possible combinations for re-ordering are $250!$ (factorial).
29 Without a map of the content provided by either the delivered SI or by a hacker, the

1 user is faced with randomly selecting each program in a stream to see if it is the
2 one interest.

3 Thus, at headend 422, the video signal 404 and the audio signal 406 are
4 provided in the clear (unencrypted) while the SI 428 is provided to multiple CA
5 systems for delivery over the cable network. Thus, in the exemplary system 400,
6 clear SI 428 is provided to an encryption system 428 that encrypts SI data using
7 encryption system A. Simultaneously, clear SI 428 is provided to encryption
8 system 424 that encrypts the SI data using encryption system B. Clear video and
9 audio are then multiplexed along with encrypted SI from 418 (SI A) and encrypted
10 audio from 424 (SI B) out of band system information 428.

11 After distribution through the cable system 32, the video, the audio, system
12 information A and system information B are all delivered to set-top boxes 36 and
13 436. At STB 36, the encrypted SI is decrypted at CA system A 40 to provide tuning
14 information to the set-top box. The set-top box tunes a particular program to allow
15 it to be displayed on television set 44. Similarly, at STB 436, the encrypted SI is
16 decrypted at CA system B 440 to provide tuning information for the set-top box,
17 allow a particular program to be tuned and displayed on television set 444.

18 An advantage of this approach is that no additional A/V bandwidth is
19 required in the content delivery system, e.g. cable system. Only the SI is dual
20 carried. No special hardware is required. Any offset frequencies from the standard
21 ones can be easily accommodated by most tuners. SI decryption can be performed
22 in software or can be aided by hardware. For example, legacy Motorola set-top
23 boxes have an ability to descramble the SI delivered in the Motorola out-of-band
24 using a hardware decrypter built into the decoder IC chip.

25 A determined hacker can potentially use a spectrum analyzer on the coax
26 cable to learn where the A/V channels are located. Also, it may be possible for the
27 hacker to program a set-top box to auto-scan the frequency band to learn where the
28 A/V channels are – a relatively slow process. If the A/V channel frequencies
29 changed dynamically, then that could foil the hackers, since they would need to be
30 constantly analyzing or scanning the band. Also, the program numbers and

1 assigned PIDs can vary. However, dynamically changing frequencies, program
2 numbers, and PIDs might create operational difficulties to a service provider, e.g.
3 cable operator.

4

5 **GENERALIZED REPRESENTATION**

6 Each of the above techniques can be represented generically by the system
7 500 of **FIGURE 10**. This system 500 has a cable system headend 522 with clear
8 video 504, clear audio 506, SI 528, and PSI 529 any of which can be selectively
9 switched through an intelligent processor controlled switch 518, which also serves
10 to assign PIDs (in embodiments requiring PID assignment or reassignment), to
11 conditional access system A 504 or conditional access system B 524 or passed
12 in the clear to the cable system 32. As previously, the program or SI encrypted
13 according to the legacy CA system A can be properly decoded by STB 36. The CA
14 system B encrypted information is understood by STBs 536 and decrypted and
15 decoded accordingly, as described previously.

16

17 **PID MAPPING CONSIDERATIONS**

18 The PID mapping concepts described above can be generally applied to the
19 dual partial encryption techniques described herein, where needed. At the cable
20 headend, the general concept is that a data stream of packets is manipulated to
21 duplicate packets selected for encryption. Those packets are duplicated and
22 encrypted under two distinct encryption methods. The duplicated packets are
23 assigned separate PIDs (one of which matches the legacy CA PID used for clear
24 content) and reinserted in the location of the original selected packet in the data
25 stream for transmission over the cable system. At the output of the cable system
26 headend, a stream of packets appears with the legacy encrypted packets and clear
27 packets having the same PID. A secondary PID identifies the packets that are
28 encrypted under the new encryption system. In addition to the PID remapping that
29 takes place at the headend, MPEG packets utilize a continuity counter to maintain
30 the appropriate sequence of the packets. In order to assure proper decoding, this

1 continuity counter should be properly maintained during creation of the packetized
2 data stream at the headend. This is accomplished by assuring that packets with
3 each PID are assigned continuity counters sequentially in a normal manner. Thus,
4 packets with the secondary PID will carry a separate continuity counter from those
5 of the primary PID. This is illustrated below in simplified form where PID 025 is the
6 primary PID and PID 125 is the secondary PID, E represents an encrypted packet,
7 C represents a clear packet, and the end number represents a continuity counter.
8

9	025C04	025E05	125E11	025C06	025C07	025C08	025C09	125E12
---	--------	--------	--------	--------	--------	--------	--------	--------

10
11 In this exemplary segment of packets, packets with PID 025 are seen to
12 have their own sequence of continuity counters (04, 05, 06, 07, 08, 09, ...).
13 Similarly, the packets with secondary PID 125 also have their own sequence of
14 continuity counters (11, 12, ...).

15 At the STB, the PIDs can be manipulated in any number of ways to correctly
16 associate the encrypted packets with secondary PID with the correct program. In
17 one implementation, the packet headers of an input stream segment illustrated
18 below:

20	025C04	025E05	125E11	025C06	025C07	025C08	025C09	025E10
----	--------	--------	--------	--------	--------	--------	--------	--------

21
22 are manipulated to create the following output stream segment:
23

24	125C04	025E11	125E05	125C06	125C07	125C08	125C09	125E10
----	--------	--------	--------	--------	--------	--------	--------	--------

25
26 The primary PIDs (025) in the input stream are replaced with the secondary PID
27 (125) for the clear packets (C). For the encrypted packets, the primary PID and
28 secondary PID are retained, but the continuity counters are swapped. Thus, the
29 stream of packets can now be properly decrypted and decoded without errors

1 caused by loss of continuity using the secondary PID. Other methods for
2 manipulation of the PIDs, e.g. mapping the PID (125) on the scrambled legacy
3 packet to a NOP PID (all ones) or other PID value not decoded, and the continuity
4 counters can also be used in embodiments consistent with the present invention.

5 The primary and secondary PIDs are conveyed to the STBs in the program
6 map table (PMT) transmitted as a part of the program system information (PSI)
7 data stream. The existence of a secondary PID can be established to be ignored
8 by the STB operating under CA encryption system A (the "legacy" system), but new
9 STBs operating under CA encryption system B are programmed to recognize that
10 secondary PIDs are used to convey the encrypted part of the program associated
11 with the primary PID. The set-top boxes are alerted to the fact that this encryption
12 scheme is being used by the presence of a CA descriptor in the elementary PID "for
13 loop" of the PMT. There typically would be a CA descriptor for the video
14 elementary PID "for loop", and another one in the audio elementary PID "for loop".
15 The CA descriptor uses a Private Data Byte to identify the CA_PID as either the
16 ECM PID or the secondary PID used for partial scrambling, thus setting up the STB
17 operating under system B to look for both primary and secondary PIDs associated
18 with a single program. Since the PID field in the transport header is thirteen bits
19 in length, there are 2^{13} or 8,192 PIDs available for use, any spare PIDs can be
20 utilized for the secondary PIDs as required.

21 In addition to the assignment of a PID for each program component or
22 selected portion thereof, a new PID may be assigned to tag ECM data used in the
23 second encryption technique. Each PID number assigned can be noted as a user
24 defined stream type to prevent disrupting operation of a legacy STB. MPEG
25 defines a reserved block of such numbers for user defined data stream types.

26 While conceptually the PID mapping at the cable headend is a simple
27 operation, in practice the cable headend equipment is often already established
28 and is therefore modified to accomplish this task in a manner that is minimally
29 disruptive to the established cable system while being cost effective. Thus, the
30 details of the actual implementation within the cable system headend are

1 somewhat dependent upon the actual legacy hardware present in the headend,
2 examples of which are described in greater detail below.
3
4

5 **Headend IMPLEMENTATIONS**

6 Those skilled in the art will appreciate that the above descriptions as related
7 to **FIGURES 2, 3, 6, 9 and 10** are somewhat conceptual in nature and are used to
8 explain the overall ideas and concepts associated with the various embodiments
9 of the present invention. In realizing a real world implementation of the present
10 invention, those skilled in the art will recognize that a significant real world issue
11 to contend with is providing a cost effective implementation of the various partial
12 encryption methods within existing legacy headend equipment at established cable
13 providers. Taking two of the primary legacy cable systems as examples, the
14 following describes how the above techniques can be implemented at a cable
15 headend.

16 First, consider a cable system headend using a Motorola brand conditional
17 access system. In such a system the modifications shown in **FIGURE 11** can be
18 done to provide a cost effective mechanism for partial dual encryption
19 implementation. In a typical Motorola system, a HITS (Headend In The Sky) or
20 similar data feed is provided from a satellite. This feed provides aggregated
21 digitized content that is supplied to cable providers and is received by a receiver /
22 descrambler / scrambler system 604 such as the Motorola Integrated Receiver
23 Transcoder (IRT) models IRT 1000 and IRT 2000, and Motorola Modular Processing
24 System (MPS). A clear stream of digitized television data can be obtained from the
25 satellite descrambler functional block 606 of the receiver / descrambler / scrambler
26 604. This clear stream can be manipulated by a new functional block shown as
27 packet selector / duplicator 610. This new block 610 may be implemented as a
28 programmed processor or may be otherwise implemented in hardware, software
29 or a combination thereof.

1 Packet selector / duplicator 610 selects packets that are to be dual
2 encrypted under any of the above partial dual encryption methods. Those packets
3 are then duplicated with new PIDs so that they can be later identified for encryption.
4 For example, if packets at the input of 610 associated with a particular program
5 have PID A, then packet selector / duplicator 610 identifies packets to be encrypted
6 and duplicates those packets and remaps them to PIDs B and C respectively, so
7 that they can be identified later for encryption under two different systems.
8 Preferably, the duplicate packets are inserted into the data stream adjacent one
9 another in the location of the originally duplicated packet now with PID C so that
10 they remain in the same order originally presented (except that there are two
11 packets where one previously resided in the data stream). Assume, for the
12 moment, that the new CA system to be added is NDS encryption. In this case, PID
13 A will represent clear packets, PID B will represent NDS encrypted packets and
14 PID C will represent Motorola encrypted packets. The packets having PID B may
15 be encrypted under the NDS encryption at this point in 610 or may be encrypted
16 later.

17 The packets with PIDs B and C are then returned to the system 604 where
18 packets with PID C are encrypted under Motorola encryption at cable scrambler
19 612 as instructed by the control system 614 associated with the Motorola
20 equipment. The output stream from cable scrambler 612 then proceeds to another
21 new device - PID remapper and scrambler 620, which receives the output stream
22 from 612 and now remaps the remaining packets with PID A to PID C and encrypts
23 the PID B packets under the NDS encryption algorithm under control of control
24 system 624. The output stream at 626 has clear unencrypted packets with PID C
25 and selected packets which have been duplicated and encrypted under the
26 Motorola encryption system with PID C along with encrypted packets under the
27 NDS encryption system with PID B. This stream is then modulated (e.g.,
28 Quadrature Amplitude Modulated and RF modulated) for distribution over the cable
29 system. The preferred embodiment maps the unencrypted packets on PID A to
30 match the scrambled packets on PID C because the audio and video PIDs called

1 out in legacy program specific information (PSI) is correct that way. The control
2 computer, the scrambler, and legacy set-top boxes only know about PID C.
3 Alternatively, the scrambled packets on PID C could be mapped back to PID A, but
4 this would likely mean editing the PSI, that was automatically generated, to map
5 the PID numbers from PID C back to PID A in the PID remapper and scrambler
6 620.

7 In the above example, the PID remapper and scrambler 620 may also be
8 used to demultiplex PSI information, modify it to reflect the addition of the NDS
9 encryption (through the use of CA descriptors in the PMT) and multiplex the
10 modified PSI information back into the data stream. The ECMS to support NDS
11 encryption may also be inserted into the data stream at PID remapper and
12 scrambler 620 (or could be inserted by packet selector / duplicator 610).

13 Thus, in order to add NDS encryption (or another encryption system) to a
14 cable system headend using Motorola equipment, packets are duplicated and PIDs
15 are remapped in the data stream from the satellite descrambler. The remapped
16 PIDs are then used to identify packets that are to be scrambled under each CA
17 system. Once the legacy system encryption has taken place, the clear PID is then
18 remapped so that both clear and encrypted packets in the legacy system share the
19 same PID (or PIDs). PID remapping as in 620 and packet selection and duplication
20 as in 610 can be implemented using a programmed processor or using custom or
21 semi-custom integrated circuitry such as an application specific integrated circuit
22 or a programmable logic device or field programmable gate array. Other
23 implementations are also possible without departing from the present invention.

24 **FIGURE 12** depicts a similar equipment configuration such as that used in
25 implementing the partial dual encryption of the present invention in a Scientific
26 Atlanta based cable headend. In this embodiment, the HITS feed or similar is
27 received at IRD 704 which incorporates a satellite descrambler 706. This may be
28 a Motorola IRT or MPS with only the satellite descrambler function enabled. The
29 output of the satellite descrambler 706 again provides a clear data stream that can
30 be manipulated by a new packet selector / duplicator 710 which selects packets

1 to be encrypted, duplicates them and maps the PIDs of the duplicate packets to
2 new PIDs. Again, for example, packets to remain in the clear are assigned PID A,
3 packets to be encrypted under the new system (e.g., NDS) are assigned PID B and
4 packets to be encrypted under the Scientific Atlanta encryption system are
5 assigned PID C. The packets with PID B may be encrypted at this point under the
6 NDS encryption system.

7 The stream of packets is then sent to a multiplexer 712 (e.g., a Scientific
8 Atlanta multiplexer) where the packets having PID C are encrypted under the
9 Scientific Atlanta encryption system at 714 under control of control system 718
10 associated with multiplexer 712. The stream of data is then supplied internal to
11 multiplexer 712 to a QAM modulator 720. In order to properly remap the packets,
12 the QAM modulated signal at the output of multiplexer 712 is provided to a new
13 processor system 724 where the QAM modulated signal is demodulated at a QAM
14 demodulator 730 and the clear PID A packets are remapped to PID C at PID
15 remapper 734 under control of a control system 738. Encryption under the NDS
16 encryption algorithm can also be carried out here rather than in 710. The data
17 stream with remapped PIDs and dual partial encryption is then QAM and RF
18 modulated at 742 for distribution over the cable system.

19 In the above example, the PID remapper and scrambler 734 may also be
20 used to demultiplex PSI information, modify it to reflect the addition of the NDS
21 encryption (adding the CA descriptors to the PMT) and multiplex the modified PSI
22 information back into the data stream. The ECMS to support NDS encryption may
23 also be inserted into the data stream at PID remapper and scrambler 734 (or could
24 be inserted by packet selector / duplicator 710). PID remapping and or scrambling
25 as in 734 along with QAM demodulation and QAM modulation as in 730 and 742
26 respectively, and packet selection and duplication as in 710 can be implemented
27 using a programmed processor or using custom or semi-custom integrated circuitry
28 such as an application specific integrated circuit or a programmable logic device
29 or field programmable gate array. Other implementations are also possible without
30 departing from the present invention.

1 The above embodiments of the present invention allow legacy scrambling
2 equipment to scramble only the packets desired in an elementary stream instead
3 of the entire elementary stream. The scrambling of certain packets of an
4 elementary stream is accomplished by using a PID number for packets that are not
5 going to be scrambled, e.g., PID A. Packets that will be scrambled will be placed
6 on PID C. The scrambling equipment will scramble the packets on PID C (the ones
7 that have been selected for scrambling). After the scrambling has taken place, the
8 unscrambled packets have the PID number mapped to the same as the scrambled
9 packet – PID A becomes PID C. The legacy set-top boxes will receive an
10 elementary stream with both scrambled and un-scrambled packets.

11 The packets in these embodiments are handled as a stream. The entire
12 stream is sent to the legacy scrambling equipment for scrambling. This keeps all
13 of the packets in exact time synchronous order. If packets were extracted from a
14 stream and sent to the legacy scrambling equipment, time jitter might be
15 introduced. The present embodiment avoids that problem by keeping all the
16 packets in a stream. The embodiment does not require cooperation from the
17 legacy scrambling equipment provider because that equipment is not involved in
18 the remapping of packets- from PID A to PID C. This remapping is preferable
19 because the PID called out by the PSI generated by the legacy scrambling system
20 does not need to change. The legacy system knows about PID C, but not PID A.
21 The entire elementary stream to be scrambled by the legacy scrambling equipment
22 is found on a single PID that the scrambling system has been instructed to
23 scramble.

24 In the above examples, the use of NDS as the second encryption system
25 should not be considered limiting. Moreover, although two widely used systems -
26 Motorola and Scientific Atlanta have been depicted by way of example, similar
27 modifications to legacy systems to permit PID remapping and dual partial
28 encryption can be used. In general, the technique described above involves the
29 process generally described as 800 in **FIGURE 13**. A feed is received at 806 which
30 is descrambled as it is received at 810 to produce a clear data stream of packets.

1 At 814, packets are selected according to the desired partial dual encryption
2 technique (e.g., audio only, packets containing PES header, etc.). At 818, the
3 selected packets are duplicated and the duplicate pairs are remapped to two new
4 PIDs (e.g., PID B and PID C). The duplicated packets are then encrypted based
5 upon PID (that is, PID C is encrypted according to legacy encryption and PID B is
6 encrypted according to the new encryption system) at 822. The clear packets (e.g.,
7 PID A) are then remapped to the same PID as the legacy encrypted PID (PID C) at
8 826.

9 The order in which some of the elements of the process of **FIGURE 13** are
10 carried out can vary according to the particular legacy system being modified to
11 accommodate the particular dual encryption arrangement being used. For
12 example, encryption under a new encryption system can be carried out either at the
13 time of duplication or later at the time of remapping the legacy packets, as
14 illustrated in **FIGURE 11** and **12**. Additionally, various demodulation and re-
15 modulation operations can be carried out as needed to accommodate the particular
16 legacy system at hand (not shown in **FIGURE 13**).

17

18 SET-TOP BOX IMPLEMENTATIONS

19 Several set-top box implementations are possible within the scope of the
20 present invention. The method used at the headend to select packets for
21 encryption is irrelevant to the STB.

22 One such implementation is illustrated in **FIGURE 14**. In this embodiment,
23 packets from a tuner and demodulator 904 are provided to a decoder circuit 908's
24 demultiplexer 910. The packets are buffered into a memory 912 (e.g., using a
25 unified memory architecture) and processed by the STB's main CPU 916 using
26 software stored in ROM memory 920.

27 Selected PIDs can be stripped from the incoming transport via the STB's PID
28 filter, decrypted and buffered in SDRAM, similar to the initial processing required
29 in preparation for transfer to an HDD in a PVR application. The host CPU 916 can

1 then "manually" filter the buffered data in SDRAM for elimination of the packets
2 containing unneeded PIDs. There are some obvious side effects to this process.
3

4 The host overhead is estimated to be about 1% of the bandwidth of the CPU.
5 In the worst case, this is equivalent to 40K bytes/Second for a 15 Mbit/S video
6 stream. This reduction is possible since at most only 4 bytes of each packet is
7 evaluated and the location is on 188 byte intervals so the intervening data does not
8 have to be considered. Each packet header in SDRAM can therefore be directly
9 accessed through simple memory pointer manipulation. Additionally, Packets are
10 cached in blocks and evaluated en masse to reduce task switching of the host.
11 This would eliminate an interrupt to other tasks upon the reception of each new
12 packet. This may produce a increased latency for starting decode of a stream upon
13 channel change to allow time for cache fill. This may be negligible depending upon
the allocated SDRAM cache buffer size.

14 The host filtered packets in the SDRAM buffer are then transferred to the A/V
15 Queue through existing hardware DMA processes and mimics a PVR
16 implementation. The filtered packets are then provided to the decoder 922 for
17 decoding.

18 A second technique for implementation in a set-top box is illustrated in
19 **FIGURE 15**. Since RISC processor A/V decoder module in 930 processes the
20 partial transport PIDs and strips/concatenates for decode, the firmware within
21 decoder IC 930 can be altered to exclude individual packets in a partial transport
22 stream based upon criteria in each packet header. Alternatively, the demultiplexer
23 910 can be designed to exclude the packets. Legacy scrambled packet(s) pass
24 through the CA module still encrypted. By using the decoder IC 930 to perform the
25 removal of the legacy scrambled packets and assuming that the packets encrypted
26 under the new encryption algorithm (e.g., NDS) is immediately adjacent the legacy
27 encrypted packet (or at least prior to next primary stream video packet) then the
28 pruning of the legacy packet in effect accomplishes the merging of a single, clear
29 stream into the header strip and video queue.

1 A third technique for implementation of partial decryption in a set-top box is
2 illustrated in **FIGURE 16**. In this embodiment, the PID remapping is carried out
3 either within a circuit such as an ASIC, Field Programmable Gate Array (FPGA),
4 or a programmable logic device (PLD) 938 or other custom designed circuit placed
5 between the tuner and demodulator 904 and the decoder IC 908. In a variation of
6 this embodiment, the decoder IC 908 can be modified to implement the PID
7 remapping within demultiplexer 940. In either case, the legacy encrypted packets
8 are dropped and the non-legacy packets re-mapped either in circuit 938 or
9 demultiplexer 940.

10 This third technique can be implemented in one embodiment using the PLD
11 depicted in **FIGURE 17**. This implementation assumes that there will be not be
12 more than one encrypted packet of a particular PID appearing in a row, thus, the
13 implementation could be modified to accommodate bursts of encrypted packets
14 such as with the M and Nth encryption arrangement described above (as will be
15 explained later). The input stream passes through a PID identifier 950 which
16 serves to demultiplex the input stream based upon PID. Primary PID packets are
17 checked for continuity at 958. If a continuity error is detected, the error is noted and
18 the counter is reset at 960.

19 The original input packet stream contains packets tagged with many PIDs.
20 The PID identifier 950 separates packets with the two PIDs of interest (primary and
21 secondary PIDs) from all other packets. This capability can be scaled to process
22 multiple PID pairs. These other packets are bypassed directly to the revised output
23 stream. This processing results in a three or four byte clocking delay.

24 Packets with the secondary PID are routed by the PID identifier 950 to a
25 continuity count checker 954 which verifies sequence integrity for this PID. Any
26 errors are noted at 956, but specific handling of errors is not relevant to
27 understanding the present invention. The packet's continuity value is preserved for
28 use in checking the sequence of packets to follow. A corresponding continuity

1 check 958 is done for packets with the primary PID using the independent primary
2 counter, and again any errors are noted at 960.

3 The secondary packet is checked for a secondary flag at 962. This Boolean
4 indicator is used to remember if a secondary packet has been processed since the
5 last clear packet. More than one secondary packet between clear packets is an
6 error in this embodiment and is noted at 964. Presence of a secondary packet is
7 remembered by setting the secondary flag at 966.

8 The continuity counter of the secondary packet is changed at 968 to fit into
9 the sequence of the clear packets. Data for this substitution comes from the value
10 used to verify continuity of the primary stream at 958. The revised packet is sent
11 out from 968 and merged into the revised stream forming the output stream.

12 After packets with primary PIDs have had their continuity checked at 958,
13 they are differentiated at 970 by the scrambling flags in the header. If the packet
14 is scrambled, the primary flag is queried at 974. This primary flag Boolean
15 indicator is used to remember if a primary encrypted packet has been processed
16 since the last clear packet. More than one encrypted primary packet between clear
17 packets is an error in this embodiment and is noted at 976 before the packet is
18 discarded at 978. Presence of a encrypted primary packet is remembered by
19 setting the primary flag at 980. If there is no downstream consumer for the primary
20 encrypted packet, it can be discarded at 978. In some cases it may be necessary
21 for the packet to continue on (in which case its continuity counter can use the
22 discarded secondary continuity value).

23 If the primary PID scramble test at 970 detects a clear packet, the state of
24 the secondary and primary flags is tested at 984. Valid conditions are neither set
25 and both set, since encrypted packets should come in matched pairs. A sequence
26 of one without the other should be noted as an error at 988. However, the order of
27 appearance is inconsequential in this embodiment. It should be noted that there
28 may be other ways to flag a primary packet for deletion other than the scrambling
29 bits in the transport header, e.g. the transport_priority bit. Also, it is possible not

1 to use any bits what-so-ever, e.g. using the primary packet's simple positional
2 information, before or after the secondary packet, as an indicator for replacement.

3 Clear packets with the primary PID then have their PID value changed at 992
4 to the secondary PID before being output in the revised output stream.
5 Alternatively, the secondary PID packets can be remapped to the primary PID
6 value. The content can be decoded when the decoder is provided with the correct
7 PID for decoding the content (whether the primary or secondary PID). Presence of
8 a clear packet also clears the primary and secondary Boolean flags.

9 In all the embodiments proposed, the secondary packet can be inserted
10 adjoining the primary packet to be replaced even when a series of primary packets
11 are tagged for replacement. However, in some instances, it may facilitate headend
12 partial scrambling if multiple encrypted packets can be inserted into the stream
13 without the intervening secondary packets. In order to accommodate multiple
14 consecutive encrypted packets (such as with the Mth and N partial encryption
15 method), the use of primary and secondary flags can be replaced with a counter
16 matching test function. Thus, in place of elements 962, 964 and 966, a secondary
17 encrypted packet counter can be incremented. In place of elements 970, 974, 976
18 and 980, a primary encrypted packet counter can be incremented. Element 984
19 can be replaced with a comparison of the primary and secondary encrypted packet
20 counters to assure that the same number of encrypted packets are received in both
21 the primary and secondary paths. Instead of clearing flags at 992, the counters are
22 cleared. Using this variation, multiple encrypted packets may be consecutively
23 received and the number received are compared to monitor the integrity of the data
24 stream. Other variations will occur to those skilled in the art.

25 The function described above in connection with **FIGURE 17** can be
26 integrated into an A/V decoder chip that functions similar to that of the
27 commercially available Broadcom series 70xx or 71xx decoder used in commercial
28 set-top boxes. **FIGURE 18** illustrates a block diagram for such a decoder chip
29 where the functions already provided in the commercial chip are essentially

1 unchanged. Normally, commercial decoder chips expect there to be a one-to-one
2 correspondence between the PIDs and program components (e.g., audio or video).

3 The decoder illustrated in **FIGURE 18** permits multiple PIDs to be
4 programmed into the decoder via a connection to the STB central processor so that
5 both primary and secondary PIDs can be handled for main audio, main video and
6 a secondary video used for picture-in-picture (PiP) functions. In this embodiment,
7 the raw data stream is received by a Packet sorter 1002 that provides a function
8 similar to that described in connection with **FIGURE 17** above to demultiplex the
9 stream of packets based upon PID. Preferably, the decoder of **FIGURE 18** carries
10 out the PID sorting function of 1002 using hard wired logic circuitry rather than
11 programmed software. Program guide and stream navigation information is output
12 for use by an STB's main processor, for example. The packets associated with the
13 main audio program are buffered in a FIFO 1006, decrypted in a decrypter 1010
14 and then buffered at 1014 for retrieval by an MPEG audio decoder 1018 as needed.
15 Decoded MPEG audio is then provided as an output from the decoder.

16 In a similar manner, packets associated with the main video program are
17 buffered in a FIFO 1024, decrypted in a decrypter 1028 and then buffered at 1032
18 for retrieval by an MPEG video decoder 1036 as needed. Decoded MPEG video
19 for the main channel is then provided to a compositer 1040 and then provided as
20 an output from the decoder. Similarly, packets associated with picture-in-picture
21 video are buffered in a FIFO 1044, decrypted in a decrypter 1048 and then buffered
22 at 1052 for retrieval by an MPEG video decoder 1056 as needed. Decoded MPEG
23 video for the picture-in-picture channel is then provided to the compositer 1040
24 where it is combined with the main channel video and then provided as a decoded
25 video output from the decoder. Other packets not associated with the main or
26 picture-in-picture channel are discarded. Of course, other functions may be
27 incorporated in the decoder chip or deleted without departing from embodiments
28 of the present invention.

1 **CONCLUSION**

2 As previously mentioned, in order to thwart a persistent threat by hackers,
3 several of the above partial encryption arrangements can be combined to further
4 enhance security. For example, the critical packet encryption can be used in any
5 combination with SI encryption, Mth an N, random encryption, time slice and other
6 techniques to further enhance security. In one embodiment, as many packets
7 would be encrypted as bandwidth is available. The amount of encryption might
8 depend on whether the content was a regular program or premium (such as a pay-
9 per-view or VOD), whether it was an adult program or a regular movie, and the
10 security level that the various cable operators feel comfortable operating. Those
11 skilled in the art will appreciate that many other combinations are possible to
12 further enhance the security of the encryption without departing from the present
13 invention.

14 The present invention, as described above in its various embodiments, has
15 been described in terms of a digital A/V system using MPEG 2 coding. Thus, the
16 various packet names and protocol specifically discussed is related the MPEG 2
17 coding and decoding. However, those skilled in the art will appreciate that the
18 concepts disclosed and claimed herein are not to be construed in such a limited
19 scope. The same or analogous techniques can be used in any digital cable system
20 without limitation to MPEG 2 protocols. Moreover, the present techniques can be
21 used in any other suitable content delivery scenario including, but not limited to,
22 terrestrial broadcast based content delivery systems, Internet based content
23 delivery, satellite based content delivery systems such as, for example, the Digital
24 Satellite Service (DSS) such as that used in the DirecTV™ system, as well as
25 package media (e.g. CDs and DVDs). These various alternatives are considered
26 equivalent for purposes of this document, and the exemplary MPEG 2 cable
27 embodiment should be considered to be an exemplary embodiment presented for
28 illustrative purposes.

29 In addition, the present invention has been described in terms of decoding
30 partially encrypted television programs using a television set-top box. However, the

1 present decoding mechanism can equally be implemented within a television
2 receiver without need for an STB, or music player such as an MP3 player. Such
3 embodiments are considered equivalent.

4 Also, while the present invention has been described in terms of the use of
5 the encryption techniques described to provide a mechanism for dual partial
6 encryption of a television program, these partial encryption techniques could be
7 used as a single encryption technique or for multiple encryption under more than
8 two encryption systems without limitation. More than two encryption systems
9 would be accommodated with additional duplicated packets that are encrypted.
10 Alternatively, the encryption key for one of the duplicated packets may be shared
11 amongst the multiple encryption systems. Additionally, although specifically
12 disclosed for the purpose of encryption of television programming, the present
13 inventions can be utilized for single or dual encryption of other content including,
14 but not limited to content for download over the Internet or other network, music
15 content, packaged media content as well as other types of information content.
16 Such content may be played on any number of playback devices including but not
17 limited to personal digital assistants (PDAs), personal computers, personal music
18 players, audio systems, audio / video systems, etc. without departing from the
19 present invention.

20 Those skilled in the art will recognize that the present invention has been
21 described in terms of exemplary embodiments that can be realized by use of a
22 programmed processor. However, the invention should not be so limited, since the
23 present invention could be implemented using hardware component equivalents
24 such as special purpose hardware and/or dedicated processors which are
25 equivalents to the invention as described and claimed. Similarly, general purpose
26 computers, microprocessor based computers, micro-controllers, optical computers,
27 analog computers, dedicated processors and/or dedicated hard wired logic may be
28 used to construct alternative equivalent embodiments of the present invention.

29 Those skilled in the art will appreciate that the program steps and associated
30 data used to implement the embodiments described above can be implemented

1 using disc storage as well as other forms of storage such as for example Read
2 Only Memory (ROM) devices, Random Access Memory (RAM) devices; optical
3 storage elements, magnetic storage elements, magneto-optical storage elements,
4 flash memory, core memory and/or other equivalent storage technologies without
5 departing from the present invention. Such alternative storage devices should be
6 considered equivalents.

7 The present invention, as described in embodiments herein, can be
8 implemented using a programmed processor executing programming instructions
9 that are broadly described above in flow chart form that can be stored on any
10 suitable electronic storage medium or transmitted over any suitable electronic
11 communication medium. However, those skilled in the art will appreciate that the
12 processes described above can be implemented in any number of variations and
13 in many suitable programming languages without departing from the present
14 invention. For example, the order of certain operations carried out can often be
15 varied, additional operations can be added or operations can be deleted without
16 departing from the invention. Error trapping can be added and/or enhanced and
17 variations can be made in user interface and information presentation without
18 departing from the present invention. Such variations are contemplated and
19 considered equivalent.

20 While the invention has been described in conjunction with specific
21 embodiments, it is evident that many alternatives, modifications, permutations and
22 variations will become apparent to those skilled in the art in light of the foregoing
23 description. Accordingly, it is intended that the present invention embrace all such
24 alternatives, modifications and variations as fall within the scope of the appended
25 claims.

26 What is claimed is:
27